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MISSION TO PLANET EARTH:

A PROGRAM TO UNDERSTAND GLOBAL ENVIRONMENTAL CHANGE

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MTPE

(NASA-TM-109697) MISSION TO PLANET EARTH: A PROGRAM TO UNDERSTAND GLOBAL ENVIRONMENTAL CHANGE (NASA) 11 p

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The Concern: The Earth is Changing

Ozone depletion. Deforestation. Global warming. Barely a decade ago, these issues interested only atmospheric and environmental scientists. Today, increasing evidence of large-scale change has made us aware of the threats to our life-sustaining global environment. From the earliest days of our planet, the Earth has experienced changes in land patterns, atmospheric composition, and ocean dynamics. However, human beings no longer are merely spectators to the drama of Earth's global change; instead, we have become active players. By increasing greenhouse gases in the atmosphere with exhaust fumes from our cars, smoke from factories and the burning of our forests; by changing the face of the natural landscape; and by producing ozone-depleting chemicals, we are for the first time in our history acting as contributing agents to worldwide environmental change. Unlike local environmental problems that affect a small area, global changes are just that—they affect the world as a whole. Within the span of a few human generations we have changed our world significantly without understanding the long-term effects on its ability to sustain life.

Observing, monitoring and understanding global change requires studying the Earth as a whole from the unique perspective of space. Only from space can we see changes occurring over the entire globe. NASA's Mission to Planet Earth uses this unique perspective to understand how the Earth's environment is changing, and how human activities contribute to it. Mission to Planet Earth is a long-term program that studies the Earth using data from satellites, aircraft, and ground studies. The program includes a data and information system available to scientists and other users around the world, and a research program to support scientific analysis of the data. The information developed from Mission to Planet Earth and other programs to understand global change will help decision makers make prudent environmental and economic policy.

Changes in the Environment: What Are the Long-term Effects?

Greater scientific understanding and research findings over the past 30 years reveal that the Earth is not a static globe, but an actively changing one. The dynamism and drama of plate tectonics have long produced patterns of volcanism and earthquake activity. The biological Earth has exerted a major influence on global processes such as ocean biota and their effect on climate through the removal of atmospheric carbon dioxide during formation of ocean sediments. The oceans, atmosphere, and ice-covered regions of the planet have contributed to shaping the Earth's weather and climate.

We do not yet know what the long-term effects of global environmental change are. The most worrisome in the coming years are the possible effects of global warming, ozone depletion, and large-scale changes in land cover due to human activity. Seeking answers to these unknowns drives the search for greater scientific understanding of the Earth and global climate change.

FIGURE 1 *Photograph taken from NASA's C-130 aircraft of the collapsed interchange of highways 5 and 14 in Northridge, CA during the Los Angeles earthquake on January 17, 1994.*

Global Warming

Scientists know that the Earth's average global temperatures have increased since the start of the Industrial Revolution, but they do not yet know to what extent the increase is natural, or to what extent the planet can adjust before potentially disastrous environmental change results. Global warming occurs in part because of the increase of certain trace gases such as carbon dioxide and methane in the atmosphere resulting from industrial and other human activities. These trace gases trap heat inside the Earth's atmosphere, similar to the glass roof of a greenhouse. Increases in global temperatures over time could change precipitation patterns and growing seasons in many parts of the world. Such warming also could melt polar ice, causing the world's oceans to rise, expand, and potentially flood the Earth's coastal and low-lying areas. We do not yet fully understand how the Earth system regulates global temperature, or whether it can adjust to continued increases in greenhouse gases from human activities. Many of Mission to Planet Earth's investigations study the factors that contribute to global warming, the rate at which it might occur in the future, the role of human activities in this change, and to what extent a shift in these activities could moderate the change.

Ozone Depletion

Ozone depletion is one of the most clearly documented cases of human activity inducing global change within the span of two generations. Ozone, a trace chemical in the stratosphere, absorbs some types of radiation, such as ultraviolet (UV). The ozone layer thus protects life on Earth from radiation that can cause cataracts, skin cancer, reduced immunity in animals, and reduces productivity in many plants. Ozone depletion occurs when ozone reacts with chlorine, bromides and other compounds in the presence of sunlight. The main source of chlorine in the stratosphere is human-produced chlorofluorocarbons (CFCs), which are used in refrigeration, air conditioners, and in industrial solvents and cleaners. When these are released, they drift up into the stratosphere, and under the right temperature and sunlight conditions, destroy ozone. The destruction of ozone has been documented through space observations since the 1970s, with depletion starkly evident over the Antarctic, and to a lesser but still serious extent, elsewhere. Because of this evidence, nations throughout the world signed the 1989 Montreal Protocol to phase out production and use of CFCs by the year 2000. Several countries, including the United States, have accelerated the phaseout as replacements for CFCs are found. Despite these actions, much still remains to be learned about the atmosphere. Mission to Planet Earth will continue to study ozone depletion, seeking to understand the atmospheric energy, chemistry, and dynamics that affect depletion and regeneration of ozone and other chemicals.

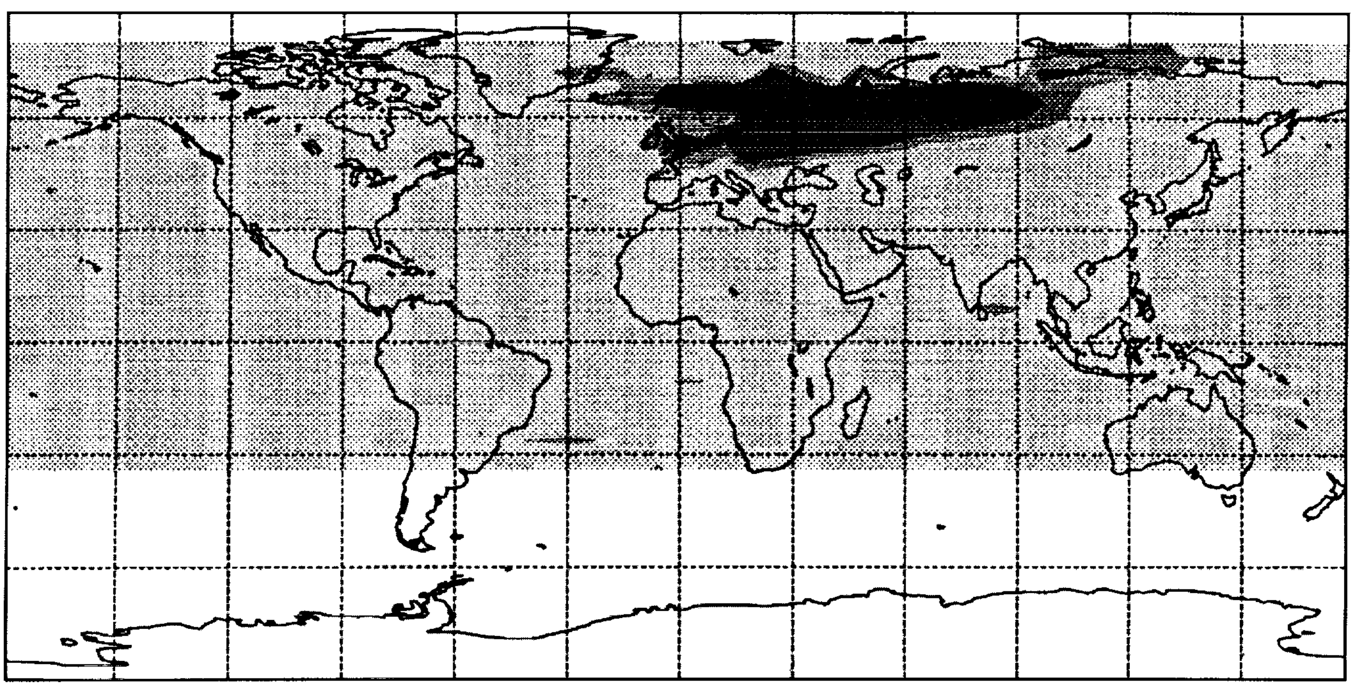

FIGURE 2 *Unusually high levels of the ozone-destroying chemical chlorine monoxide (ClO), a constituent of CFCs, were measured in Jan. 1992 over northern Europe and Russia by satellite. These levels (shown by the dark area) could cause considerable ozone depletion if certain atmospheric conditions, such as very cold temperatures, are right.*

FIGURE 3 *Deforestation where the forest is felled completely. Larger logs are removed for lumber use.*

Deforestation

Human impacts on Earth are most visible in changes to the land. As the human population has grown, we have altered the landscape for agriculture, to harvest timber, and to build cities and towns. Deforestation and changes to land have three major environmental impacts: 1) they reduce the planet's ability to absorb carbon dioxide, a major greenhouse gas, 2) they influence local weather and climate, especially affecting precipitation and water storage patterns, and 3) they reduce biodiversity. Plants, through photosynthesis, transform carbon dioxide in the air into organic matter, which either stays in the plants or is stored in soils. This process provides "storage" (called a sink) for carbon dioxide. Deforestation and clearing land releases stored carbon into the atmosphere (often through burning), and reduces the plant matter available for subsequent carbon absorption. Mission to Planet Earth will study global vegetation and other land processes to understand better their role in regulating the global climate.

Our Response: Searching for Answers

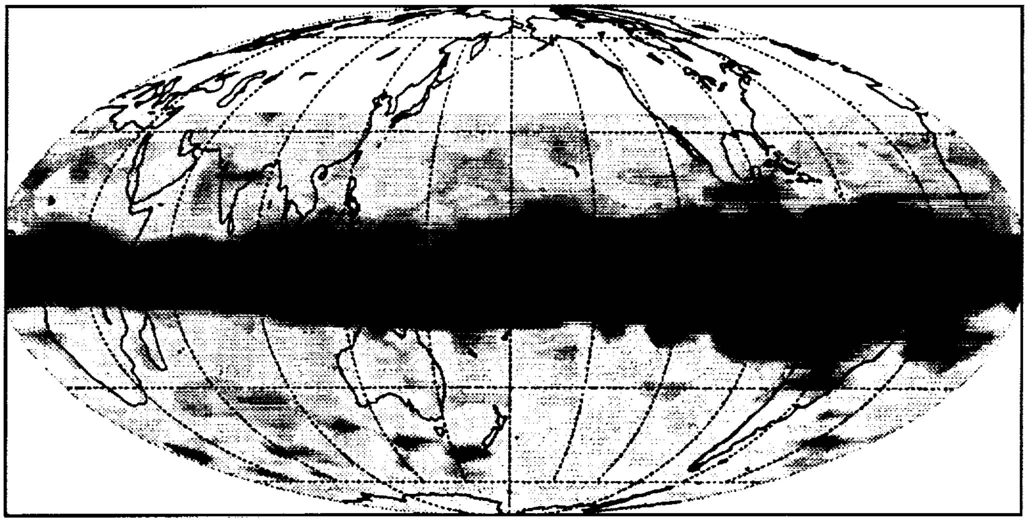

FIGURE 4 *Sulfur dioxide from the eruption of Mt. Pinatubo as observed by UARS in Sept. 1991. The volcanic plume appears as a belt of high (dark) concentration in the tropics.*

The environmental concerns that face us are global and complex. Because these phenomena potentially pose such a great risk to biodiversity and quality of life, scientists from all over the world are seeking a greater understanding of how the Earth responds to global environmental change. We cannot yet unravel the interrelationships between elements of our changing planet, do not yet know the long-term consequences of human activity, nor how we might alter our behavior either to forestall or adapt to such changes. To do so, we must understand how the Earth's environment works, and to what extent our behavior affects it, in order to make effective, balanced policy decisions.

Scientists try to distinguish between changes that humans cause and those that occur naturally. For example, volcanic eruptions such as the 1991 eruption of Mount Pinatubo in the Philippines inject large quantities of dust, gases, and aerosols into the atmosphere that produce short-term effects similar to climate change. Aerosols from the eruption of Mount Pinatubo cooled global temperatures through 1993. Because eruptions are natural variations in the climate record, studying volcanoes provides valuable information to global climate change researchers.

Scientists conduct global change research by using measurements from space and from ground studies to create computer models of Earth processes. These models simulate how the atmosphere, land, and oceans interact as a system. Scientists hope that as the data from Mission to Planet Earth and other programs are integrated into these models, it will be possible to understand better the roles of particular aspects of the global environment, as well as to predict how the environment will change over time. Building accurate models is a complex task. NASA and other agencies involved in global change studies hope that through a combination of better global data from space observations, faster computers, and improved modeling techniques, global change data can be turned into information relevant for making policy.

U.S. Global Change Research Program: Tackling the Questions

Our need to understand the global environment requires that we study the Earth beyond traditional disciplinary boundaries, such as oceanography, atmospheric chemistry, etc. It means probing interactions that shape the Earth's evolution, a task that cannot be accomplished within the bounds of any one scientific discipline. The United States responded to the challenge of global change with the creation of the U.S. Global Change Research Program (USGCRP) in 1989. The USGCRP comprises a comprehensive scientific research agenda that fosters an entirely new approach to Earth science—one that is truly interdisciplinary in approach. Mission to Planet Earth is NASA's contribution to the USGCRP.

NASA Satellites (Launch Status)	Mission Objectives
ERBS (Operating) Earth Radiation Budget Satellite	Radiation budget, aerosols, and ozone
TOMS/Meteor-3 (Operating) Total Ozone Mapping Spectrometer	Ozone mapping and monitoring (joint with Russia)
UARS (Operating) Upper Atmosphere Research Satellite	Stratospheric and mesospheric chemistry
TOPEX/Poseidon (Operating) Ocean Topography Experiment	Ocean circulation (joint with France)
LAGEOS-2 (Operating) Laser Geodynamics Satellite	Crustal motion and Earth rotation (joint with Italy)
NASA Spacelab Series (1992 on) Shuttle-based experiments	Atmospheric and solar dynamics (ATLAS), atmospheric aerosols (LITE), and surface radar backscatter, polarization, and phase function [SIR-C and X-SAR (joint with Germany)]
SeaWiFS (July 1994) Sea-Viewing Wide Field Sensor	Ocean primary production (data purchase)
TOMS/Earth Probe (July 1994) Total Ozone Mapping Spectrometer	Ozone mapping and monitoring
NSCAT/ADEOS (February 1996) NASA Scatterometer	Ocean surface wind speed and direction (joint with Japan)
TOMS/ADEOS (February 1996) Total Ozone Mapping Spectrometer	Ozone mapping and monitoring (joint with Japan)
TRMM (August 1997) Tropical Rainfall Measuring Mission	Precipitation, clouds, and radiation in low latitudes (joint with Japan)
Landsat-7 (January 1998) Land Remote-Sensing Satellite	Land surface features at high spatial resolution

FIGURE 5 *MTPE Phase I: NASA satellites and their mission objectives.*

Satellites (Launch Status)	Mission Objectives
EOS-AM Series (1998) Earth Observing System Morning Crossing (Descending)	Clouds, aerosols and radiation balance, characterization of the terrestrial ecosystem; land use, soils, terrestrial energy/moisture, tropospheric chemical composition; contribution of volcanoes to climate, and ocean primary productivity (includes Canadian and Japanese instruments)
EOS-COLOR (1998) EOS Ocean Color Mission	Ocean primary productivity
POEM-ENVISAT Series (ESA—1998) Polar-Orbit Earth Observation Mission Environmental Satellite	Environmental studies in atmospheric chemistry and marine biology, and continuation of ERS mission objectives
ADEOS IIa and IIb (Japan—1999) Advanced Earth Observing Satellite IIa and IIb	Visible and near-infrared microwave radiance/reflectance, scatterometry, infrared and laser atmospheric sounding, tropospheric and stratospheric chemistry, and altimetry (may include French and U.S. instruments)
EOS-PM Series (2000) Earth Observing System Afternoon Crossing (Ascending)	Cloud formation, precipitation, and radiative properties; air-sea fluxes of energy and moisture; and sea-ice extent (includes European instruments)
EOS-AERO Series (2000) EOS Aerosol Mission	Distribution of aerosols and greenhouse gases in the lower stratosphere (spacecraft to be provided through international cooperation)
POEM-METOP Series (ESA—2000) Polar-Orbit Earth Observation Mission Meteorological Operational Satellite	Operational meteorology and climate monitoring, with the future objective of operational climatology (joint with EUMETSAT and NOAA)
TRMM-2 (Japan and NASA—Proposed for 2000) Tropical Rainfall Measuring Mission	Precipitation and related variables and Earth radiation budget in tropics and higher latitudes
EOS-ALT Series (2002) EOS Altimetry Mission	Ocean circulation and ice sheet mass balance (may include French instruments)
EOS-CHEM Series (2002) EOS Chemistry Mission	Atmospheric chemical composition; chemistry-climate interactions; air-sea exchange of chemicals and energy (to include an as yet to be determined Japanese instrument)

FIGURE 6 *MTPE: Earth Observing System era: Satellite launch status and mission objectives.*

NASA's Role in Global Change Research

Since its inception, NASA has studied the Earth's changes from space. Scientists use data from space-based instruments to study the atmosphere, oceans, land, ice, and snow, and how these components influence and interact with climate and weather. The perspective from space is a unique one; it allows us to see our planet as a single, unified system.

Past and ongoing NASA satellite missions have used a variety of remote-sensing instruments to study components of the Earth system. For example, the Coastal Zone Color Scanner (CZCS) on the Nimbus-7 satellite launched in 1978 provided extensive observations of the oceans' biological productivity. The Total Ozone Mapping Spectrometer (TOMS) on the same satellite has returned 14 years of data on global ozone levels and helped identify the Antarctic "ozone hole." The Earth Radiation Budget Experiment (ERBE), carried by three satellites launched in the mid-1980s, has been the primary source of data for studying the heating and cooling of the atmosphere. These data may tell us the extent to which global warming is occurring.

NASA's Program: Mission to Planet Earth

Mission to Planet Earth (MTPE) studies the Earth's environment—air, water, land, living matter, and their interactions—to learn more about monitoring and understanding global climate changes. NASA's program involves observations from spacecraft, airplanes, and the ground, scientific research, and data processing and modeling to understand the Earth as a system. Phase I of MTPE already has begun. This phase—composed of ongoing and near-term missions, and small, focused missions called Earth Probes—includes more than 30 missions prior to 1998 to study various aspects of the Earth system. These missions will pave the way for the broader focus and coverage planned as part of the Earth Observing System (EOS) slated for later this decade.

Scientific investigations already are well underway, contributing to our knowledge of the Earth and its climate system. Individually and as teams, EOS scientists are forging interdisciplinary collaborations and training the next generation of Earth system scientists. The NASA Global Change Student Fellowship Program began in 1990 to ensure a pool of highly qualified Earth scientists who can use data generated during the EOS missions.

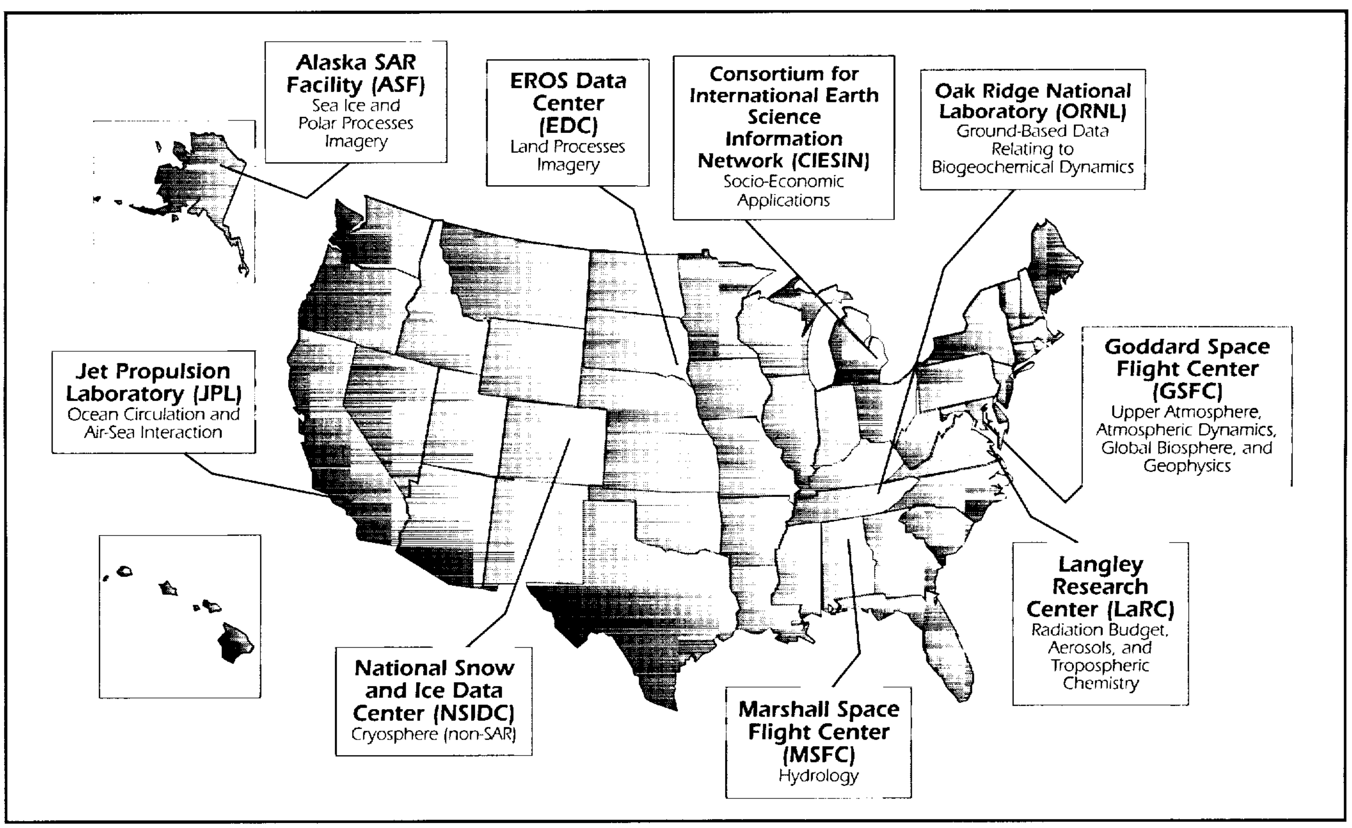

FIGURE 7 *Geographic distribution of EOSDIS.*

Ongoing and Near-Term Missions

To gain near-term information on global change, NASA has an ongoing program to provide important data sets for research today. These missions include satellites such as the Upper Atmosphere Research Satellite (UARS), launched in 1991 to study the chemistry of the upper atmosphere, and the joint U.S./French Ocean Topography Experiment (TOPEX/POSEIDON) launched in 1992 to study ocean circulation.

Besides satellite missions, NASA also conducts missions aboard the Space Shuttle, such as the Atmospheric Laboratory for Applications and Science (ATLAS). The ATLAS program investigates how both the sun and products of industrial and agricultural activities on Earth influence our planet's middle and upper atmospheres and climate. NASA also cooperates closely with efforts of other nations, providing instruments for flight on international spacecraft and arranging for exchanges of data.

Earth Probes

The Earth Probes program includes smaller, specialized U.S. satellites that will be launched before and possibly during the EOS space-flight period. Instruments on Earth Probe satellites will be used for investigations requiring different orbits than those of the generally larger EOS platforms. Missions planned under this program include the NASA Scatterometer (NSCAT) that will study ocean surface wind speed and direction; the Tropical Rainfall Measuring Mission (TRMM) that will study precipitation, clouds, and radiation in low latitudes; and the Total Ozone Mapping Spectrometer (TOMS) that will map and monitor global ozone. Several TOMS instruments have flown onboard satellites already.

The Focus of MTPE: Earth Observing System

Phase II of Mission to Planet Earth is the Earth Observing System (EOS), a series of 17 spacecraft planned for launch into near-Earth orbit. As the core of Mission to Planet Earth, the EOS instruments will make the first long-term, wide-spread measurements of the interrelated elements of the Earth system. Together, these satellites will monitor a wide array of physical, chemical, and biological processes that influence Earth system measurements on a global scale.

Each EOS spacecraft will focus on a different aspect of global climate change and different aspects of complex interactions within the Earth's environment. The first satellite in the series is scheduled for launch in 1998, and will observe the Earth's surface, clouds, aerosols, and radiation balance. Satellites dedicated to other aspects of the Earth system will follow this mission. The EOS schedule targets a minimum of 15 years of continuous Earth observations.

To allow wide use of the information from the EOS, NASA is developing the unique EOS Data and Information System (EOSDIS). EOSDIS will enable quick and easy access to data for a broad range of users, and will encourage cooperative use of global climate change research. It will process, store, and distribute critical information to thousands of international scientists and other users. Scientists will evaluate environmental data and design global climate models needed to help us understand the complex nature of the Earth's environment; eventually, these models may help us predict how the Earth will change in the future or what effect specific human activities may have. These data also will become available to a broader community of users studying the social and economic implications of global change.

MTPE: How NASA's Program Fits with Other Programs

NASA is pursuing Mission to Planet Earth in cooperation with other U.S. government agencies. Through the U.S. Global Change Research Program, NASA coordinates its efforts with those of the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency, the U.S. Geological Survey, the National Science Foundation, the Department of Agriculture, the Department of Defense, and other U.S. agencies.

All phases of Mission to Planet Earth involve significant international cooperation. NASA coordinates activities with its partners through various international groups for Earth science studies, including the International Geosphere-Biosphere Program and the World Climate Research Program. Through the Earth Observations International Coordination Working Group, the United States, Europe, Japan, and Canada are coordinating their programs to create an International Earth Observing System (IEOS). Other nations also are making satellite and instrument contributions, while an even broader set of nations will contribute aircraft observations, ground research, and/or scientific analysis. An extensive, international effort will greatly enhance our knowledge of global change.

Conclusions: Studies to Enhance Our Understanding

Mission to Planet Earth will play a critical role in the national and international efforts to understand the global environment, enhancing our awareness of ongoing natural and human-induced global change. While global data gathered from space are crucial to an understanding of the Earth system as a whole, these data mark only the first step. Even more important are the science programs at NASA and other agencies that strengthen and motivate this effort, and will translate information into comprehensive understanding.

Through a better understanding of the causes of global change, policy makers will be able to find solutions to potential large-scale environmental problems. Using both the immediate information gathered by measurements from space and models constructed from this data, policy makers and the public will be able to make the careful decisions to ensure the long-term welfare of our planet.

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